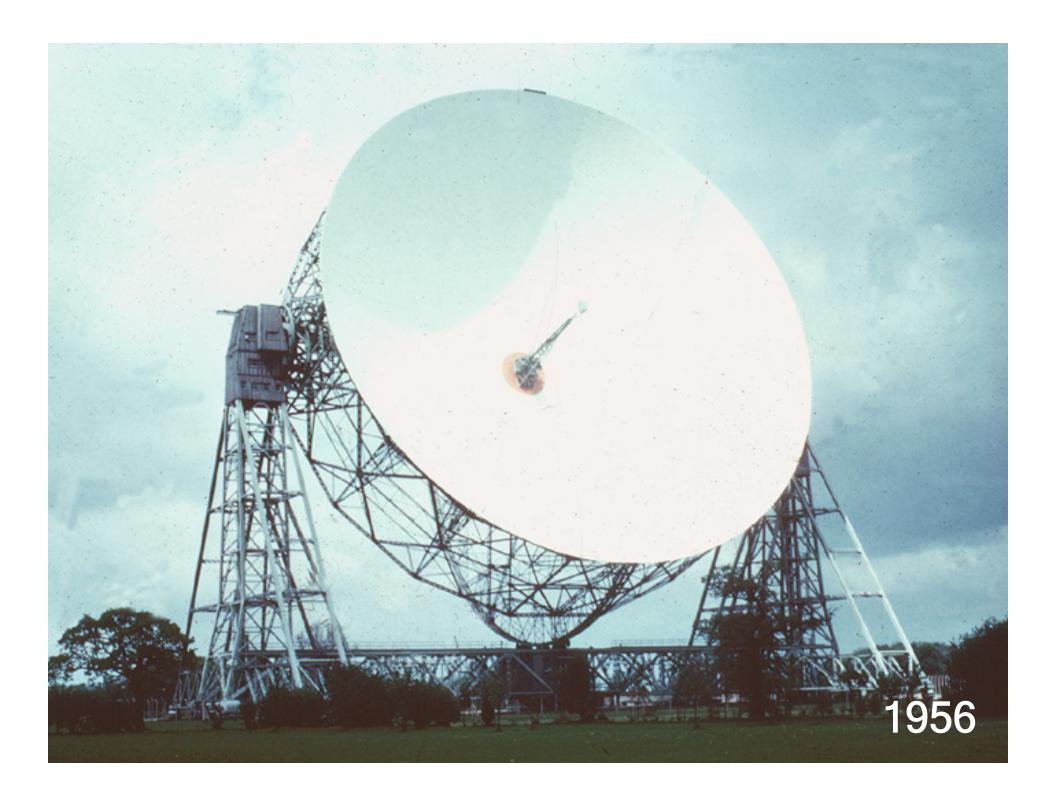


WWII

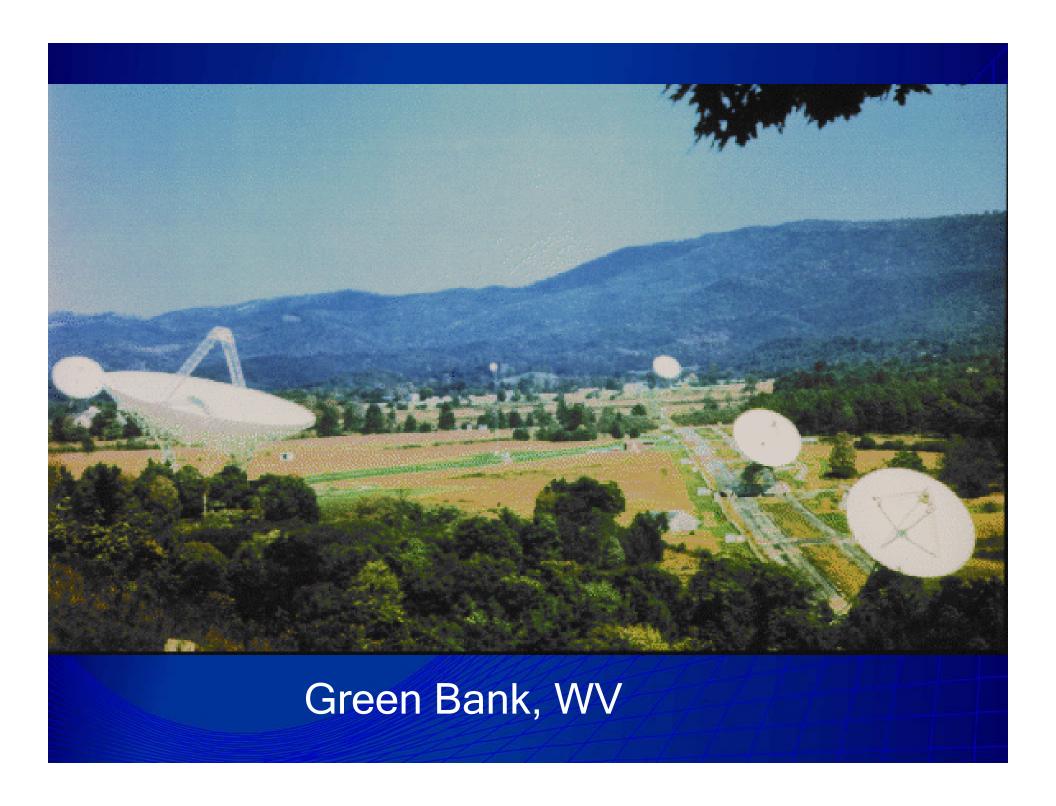
- Large resources put into radio, radar technology worldwide
- During war: J.S. Hey (UK) finally discovered radio emission from the Sun, also NZ group (early morning jamming..)
- After war: UK, Australia, Netherlands moved expertise and resources in "radio astronomy"



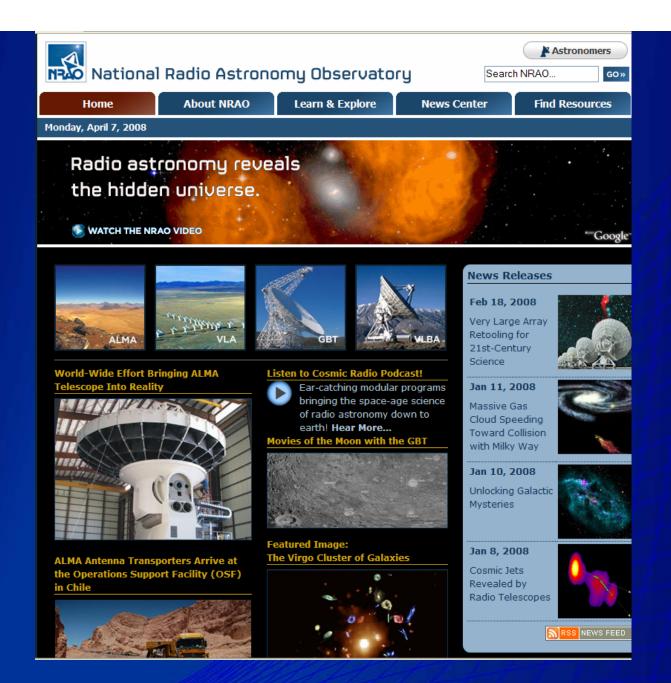




- In US: postwar slump
- mid 1950s Caltech interested.... Followup optical discoveries...
- National Radio Astronomy Observatory provide facilities to university community..
- Green Bank: single dishes, early interferometers....
- Late 60's → Very Large Array



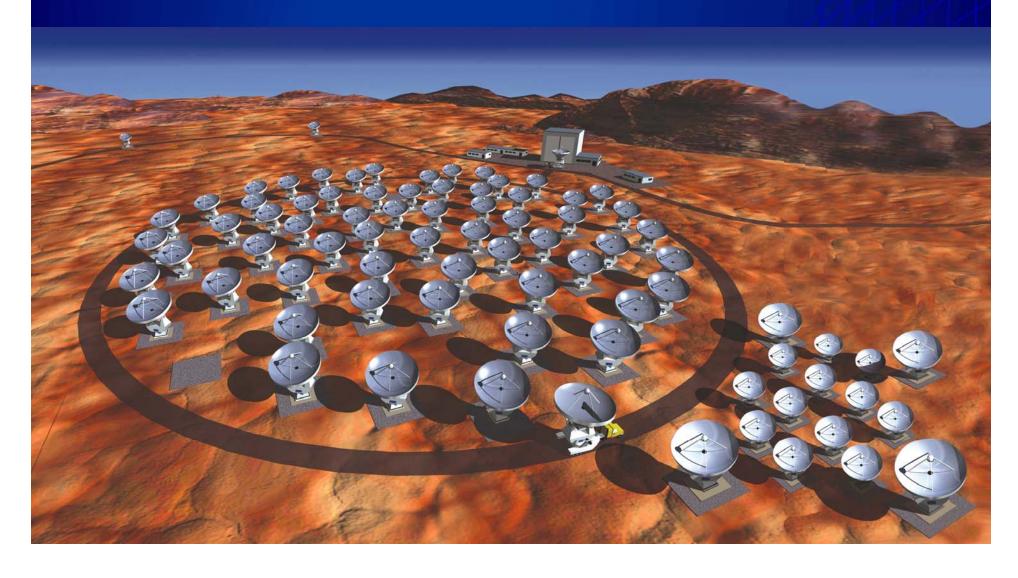




NRAO - preeminent RA org amongst 4-5 worldwide...



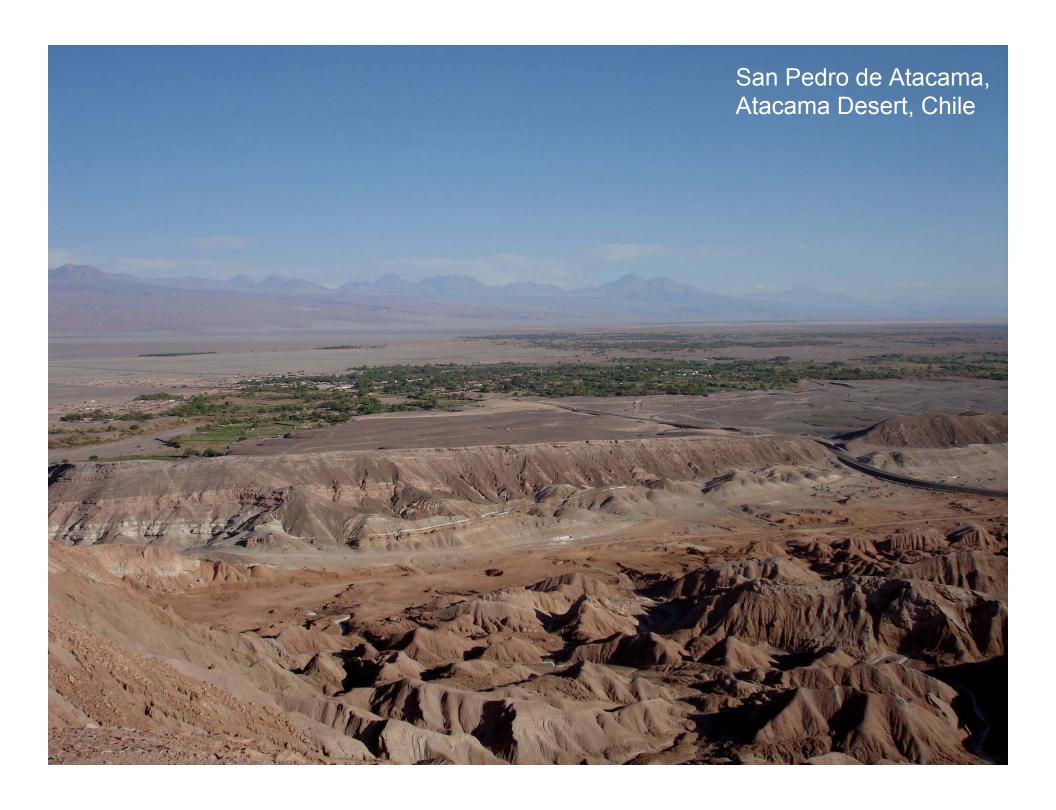


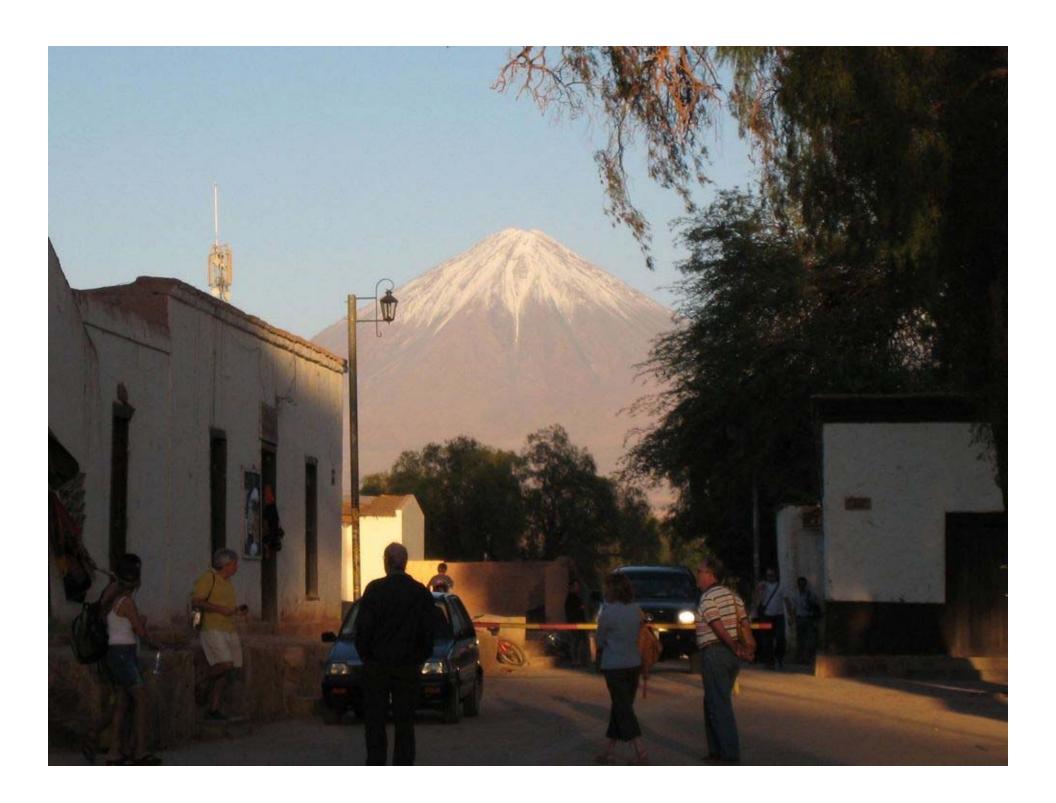


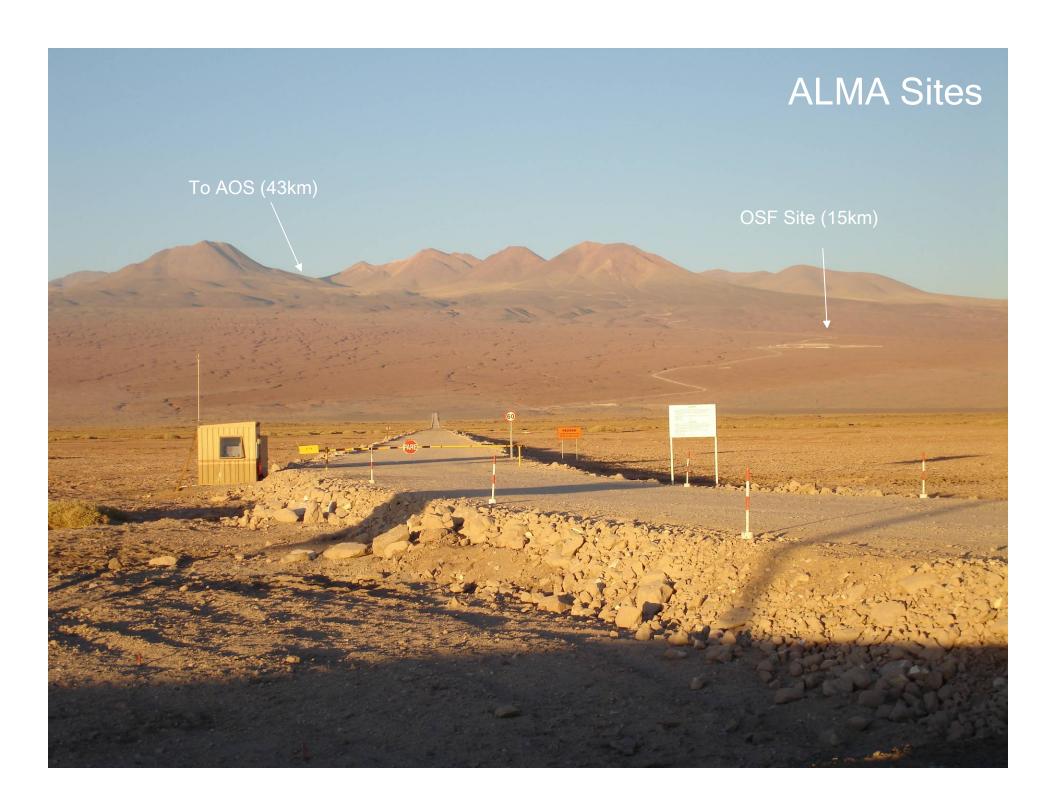
ALMA

- International project to build & operate a large (66-antenna) millimeter/submm (λ ~0.3-3mm) array at high altitude site (5000m) in northern Chile.
- Partnership between US+CA, Europe (ESO), Japan/Taiwan, Chile.
- Status: prototyping began late 90's; construction project began in 2002; rebaselined 2005; site construction underway, hardware & software in production; seven antennas in early 2008; early science ~2010, full science 2012.







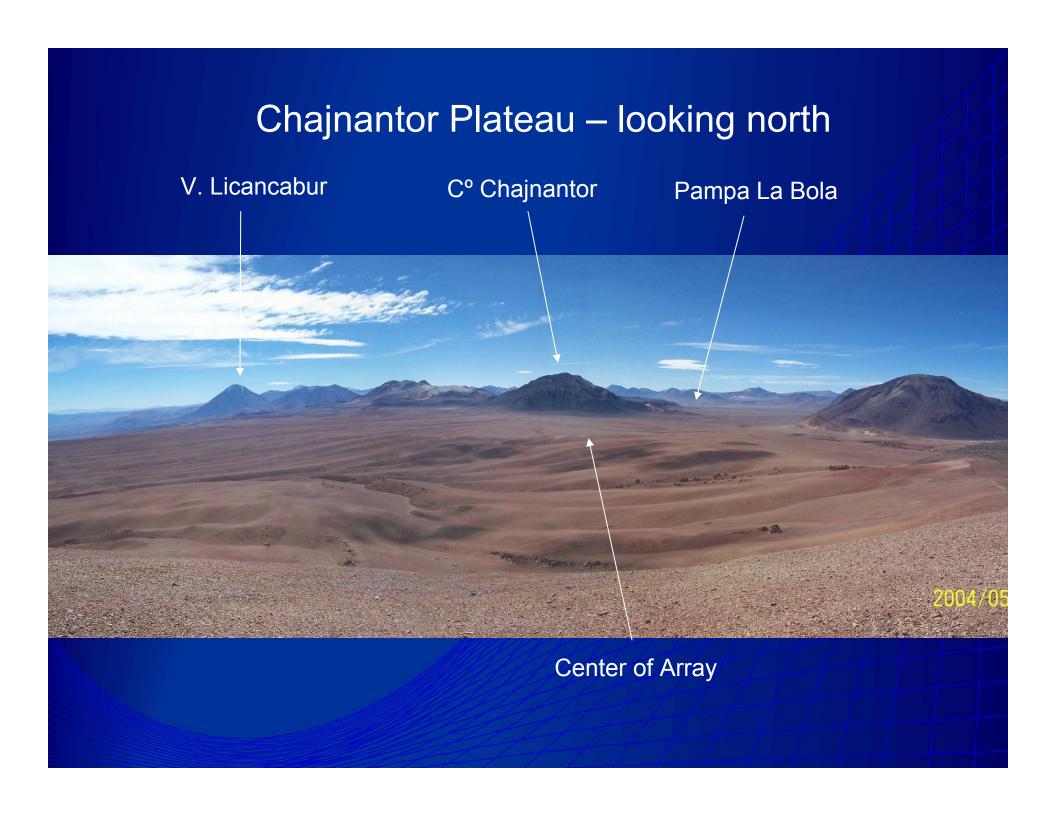




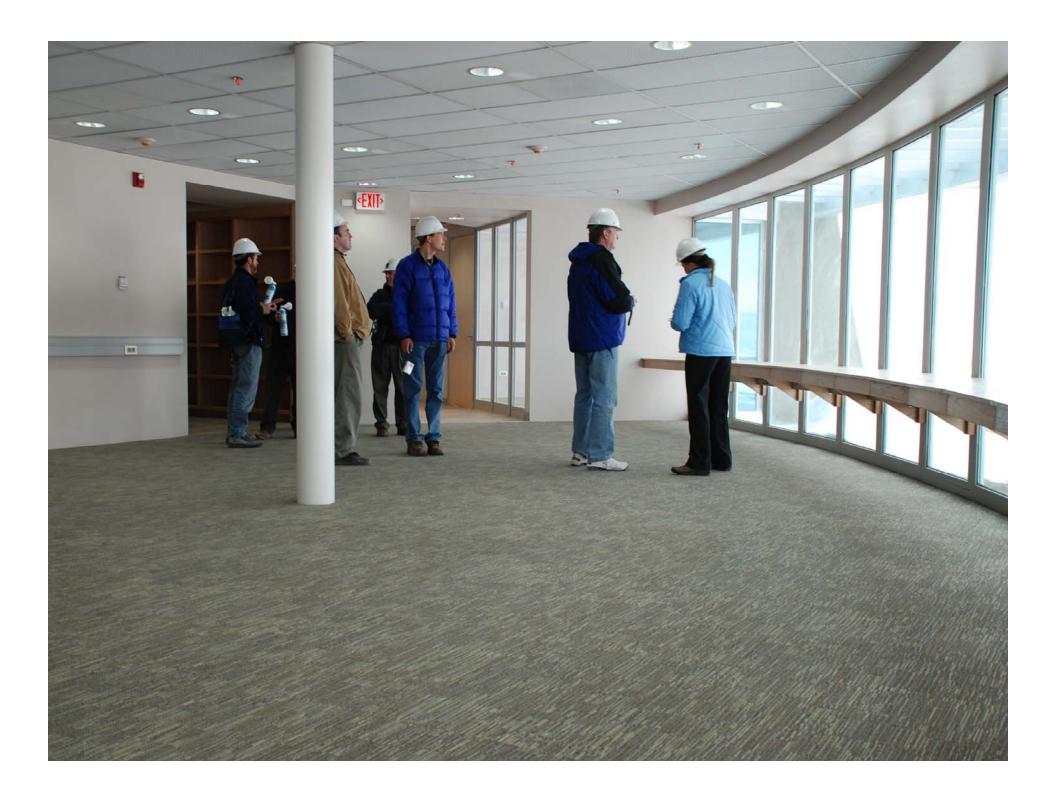




















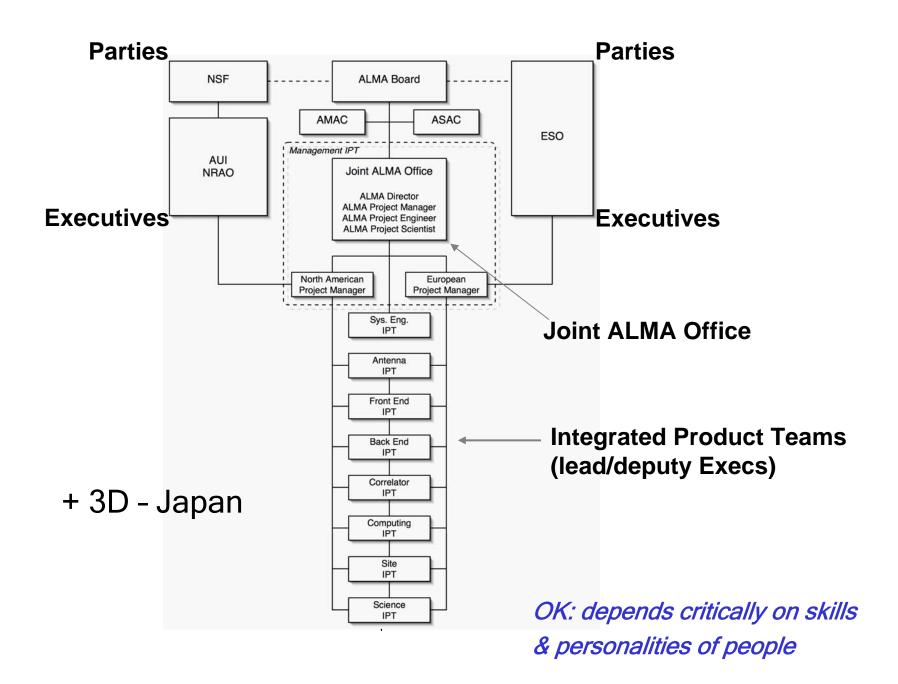


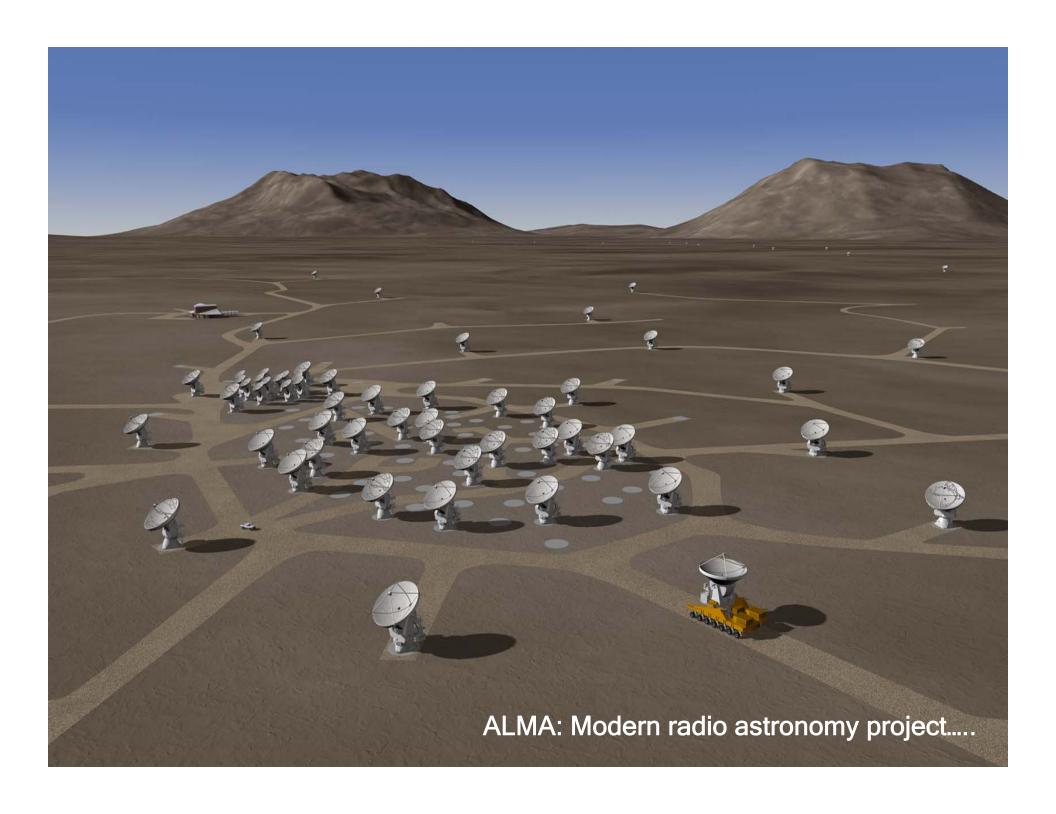
The ALMA Antenna Transporter



ALMA

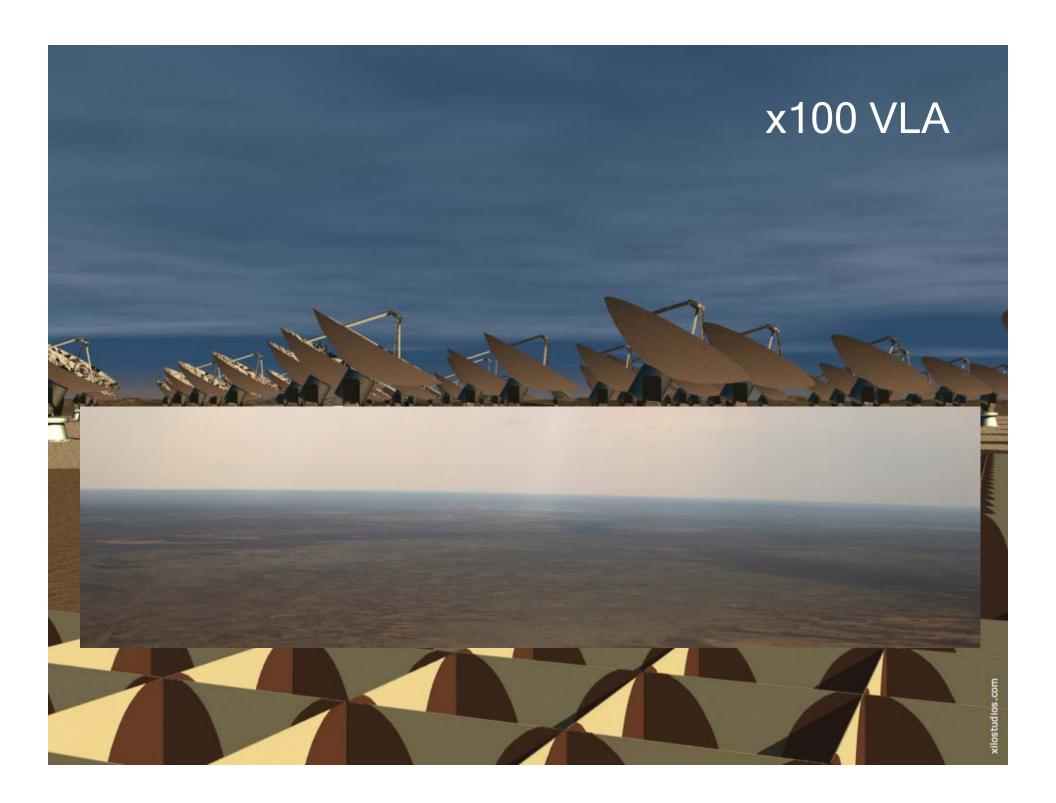
- ALMA concept: mid 90s....
- Original project budget (2002): \$592M Y2K
- 2004-2005: rebaselining (scope, budget, sched)
- Budget: 40% (\$231M)↑ N: 64→50, scope change
- Complex multi-currency, 10-yr budget
- Total cost: US\$1.3B then-yr (\$0.5B NA)
- Operating budget ~\$65M/yr, ramping to 2007-2012...
- Construction: 43% complete, \$8M/month (antennas)
- AIVC activities: calibration observations at OSF





Future Radio: Square Kilometer Array

- Next-generation radio telescope
- One million square meters of collecting area (x100)
- International project
- 5-10 years away... (3?)
- \$1 Billion+ (5?)



Issues/lessons for NRAO & ALMA

ALMA

- International collaboration... scale & cultural differences affect decision processes
- time zones: communications hard... (7-11 email)
- Difficult birth & growing pains → 50-50% partnership?
- Offshore operations.... South American politics, cost, oil, currency fluctuations, war.. "science meets world"
- Staffing in remote areas... attracting NA staff overseas...
- Scale of project demands formal PM: ALMA partners transition from home-grown/university/lab styles..
- Technical: power, data communications... \$\$\$..
 Cost of delay ≈ uncertainties sometimes...

- Safety: critical, monitored weekly, well-funded; altitude, road safety, security: strong, visible component of ops.
- Cyber security... OK. Remote access ok.
- Managing the construction to operations transition...
 ALMA: different teams ⊗ But: separation ⇒ interface, joint development ⇒ unmanageable?
- LARGE Contracts with LARGE vendors (e.g. antennas)...
 hard to affect process, performance.

NRAO: many of the above, plus...

- Multiple sites, science goals inter-site issues
 "One observatory" across four sites? Value added?
- Aging instruments... replacement costs...
- Aging staff "VLA crowd" retiring.... (staffing remote sites)
- Balancing ops vs. development projects... zero sum
- Science funding & planning... 3-5yr fluctuations... e.g. senior review outcomes... achieving long-term goals hard.
- Leading-edge radio science ⇒ larger investments... large
 %ge of current total AST budget: community interaction
- NRAO: difficulty establishing good EPO program...
- Use "scientific" managers.. Science Management

(Radio) Astronomy Issues

- All of the above, magnified....
 - SKA: x2 (5?) of current scale in all params: cost, international collab, remote operations, data transfer, power, hiring...
 - SKA: scientific return vs. total investment...
 EPO <u>astro is not biology, medical research</u>...
 - Astronomy: (more) soft vs. (less) hard money workforce pattern shift.... e.g. location, salary, permanency
 - Black-box commitment of modern astronomy will not produce the next generation of instrument developers - more science? Observatory needs vs. community wants..

- Environmental issues for new observatories... e.g. avoidance of decommissioning issues...
- International collaboration: difficult to produce something greater than sum of parts... slow decision process
 ALMA: DS: "confederation"... Long-term drag on development program.
- Projects: politics makes the big decisions?
- Academic resistance to clear chain-of-command...
- Global use "scientific" managers.. Science Management
- Example: managing risk....
- Transition from construction to operations. Shift to long overlap periods, each a large planning effort... fertile area for experience sharing, NSF conference?

NSF Issues/Challenges

- ALMA process, startup atypical in future...
 more/better project planning/management up front...
- International aspects difficult but inevitable.. NSF develop standard international interface
- NSF process: procurement thresholds, processing times etc. ... ~ok, faster? scalable?
- Reviews: how much, by whom? CYA meetings vs. useful input to projects.... Peer review vs professional input. TB: NSF fluctuates in handson/hands-off approach?
- Understand how R&D risks enter planning... EV variances, schedule delays etc. BUT: #1....

Funding

- Astronomy: several projects in MREFC queue...
 decadal review process (science), complex
 ground/space-based interaction NSF
 responsive, but volume of requests increasing..
- "Two pots of \$\$" approach construction & operations does not scale.... AST responses (e.g. Senior Review) face hostile reception, don't solve larger issue... "total activity accounting"?
- Future: NSF: internal (funding) and external (international collaboration) changes required (example: NSF & NASA model -?)
- \$\$\$ = answer.... guarantee AST share... shared setting of priorities...